HL 20.4 – Organic Condensation Reactions

IB Chemistry

T20D02

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20.4 – Condensation Reactions

- 20.4.1 Describe, using equations, the reactions of alcohols with carboxylic acids to form esters, and state the uses of esters. (2)
- 20.4.2 Describe, using equations, the reactions of amines with carboxylic acids. (2)
- 20.4.3 Deduce the structures of the polymers formed in the reactions of alcohols with carboxylic acids. (3)
- 20.4.4 Deduce the structures of the polymers formed in the reactions of amines with carboxylic acids. (3)
- 20.4.5 Outline the economic importance of condensation reactions. (2)

Formation of Esters:

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20.4.1 Describe, using equations, the reactions of alcohols with carboxylic acids to form esters, and state the uses of esters. (2)

- Condensation Reactions result from the addition of two molecules with the elimination of a small water molecule such as water.
- Known as addition/elimination
- Significant as you look into the chemistry of biological processes.
- An example of a condensation reaction is one known as **esterfication** where:
  - Carboxylic acid + alcohol (H^+ cat) → ester + water

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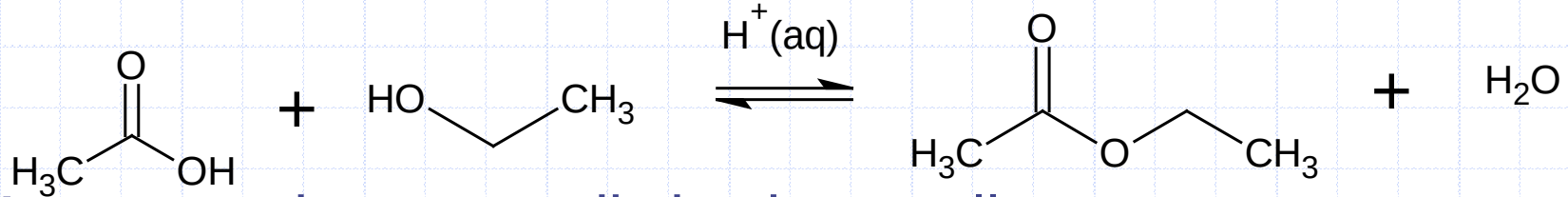
Esterfication Formation and Esters

- Ethanoic Acid + Ethanol → Ethylethanoate + Water



- Most esters have very distinctive smells
  - Generally fruity and used in perfumes and food flavorings. Also used as solvents, painkillers, anesthetics

Ester	Structural Formula	Smell or Flavor
Ethyl 2-methyl butanoate	$CH_3CH_2CH(CH_3)COOCH_2CH_3$	Apple
3-methylbutyl ethanoate	$CH_3COOCH_2CH_2CH(CH_3)CH_3$	Pear
1-methylbutyl ethanoate	$CH_3COOCH(CH_3)CH_2CH_2CH_3$	Banana
Butyl butanoate	$CH_3CH_2CH_2COOCH_2CH_2CH_2CH_3$	Pineapple
Octyl ethanoate	$CH_3COO(CH_2)_7CH_3$	Orange
Methylpropyl methanoate	$HCOOCH_2CH(CH_3)CH_3$	Raspberry
Pentyl butanoate	$CH_3CH_2CH_2COO(CH_2)_4CH_3$	Strawberry

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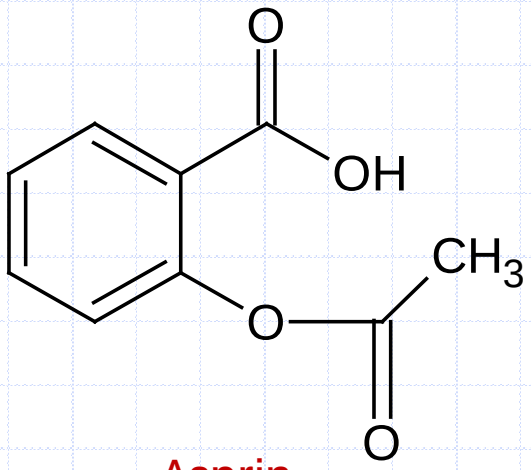
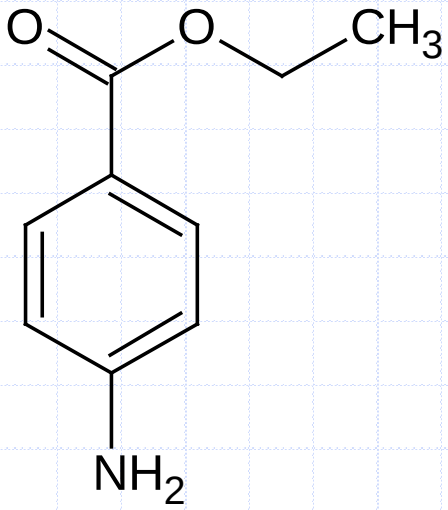
Benzene Structures with Esters

- Painkillers, such as asprin, include esters



Asprin



Benzocaine

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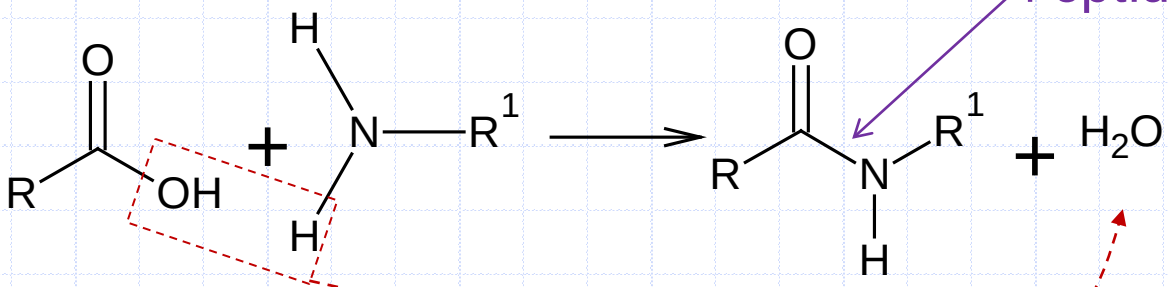
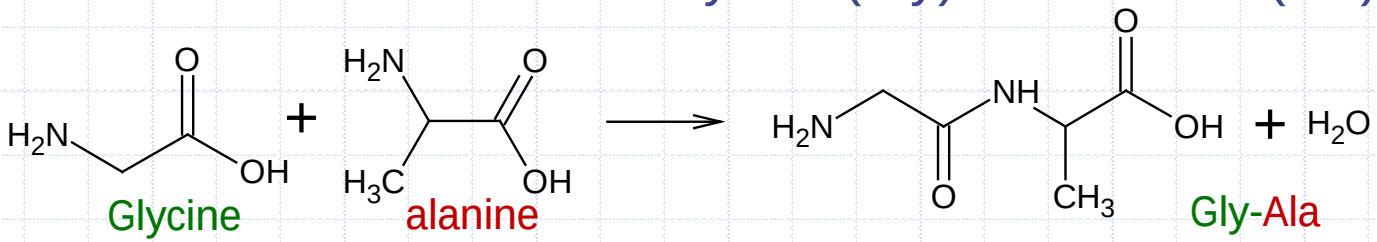
Amines with Carboxylic Acids

20.4.2 Describe, using equations, the reactions of amines with carboxylic acids. (2)

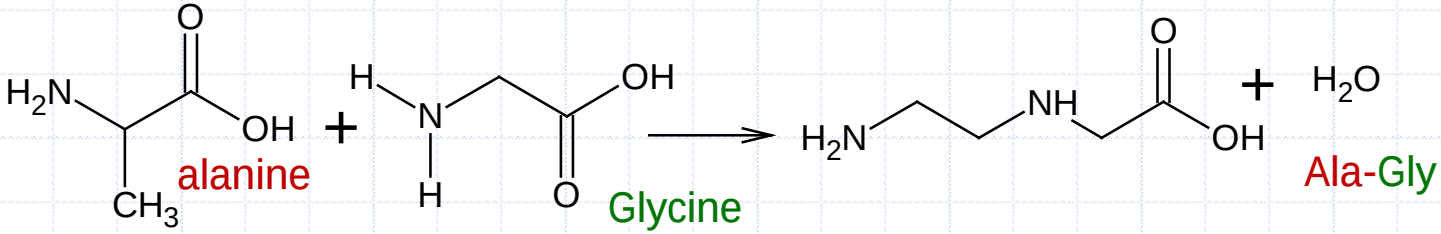
- Amines react with carboxylic acids to form secondary amides with a –CO-NH- grouping of atoms



- Amino acids in Biology (Form 2-amino acids – dipeptides):
  - Formation of 2-amino acid with Glycine (Gly) and Alanine (Ala)



  - Formation of 2-amino acid with Alanine (Ala) and Glycine (Gly)



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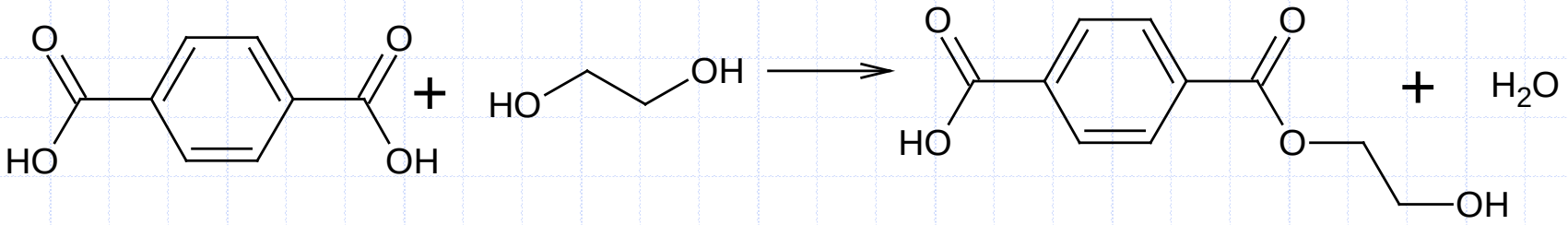
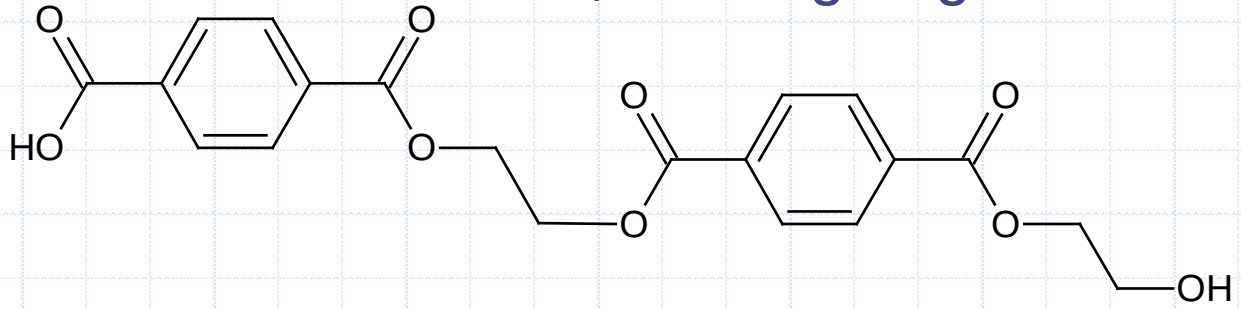
Structures of Esterification Polymers: Polyesters

20.4.3 Deduce the structures of the polymers formed in the reactions of alcohols with carboxylic acids. (3)

- In reference back to esters, an alcohol and carboxylic acid can be joined through condensation.
- Alcohols that contain more than one –OH group can polymerize to form **polyesters** or a **condensation polymer**



- Since the product still has multiple –OH groups, polymerization can continue, forming larger molecules:



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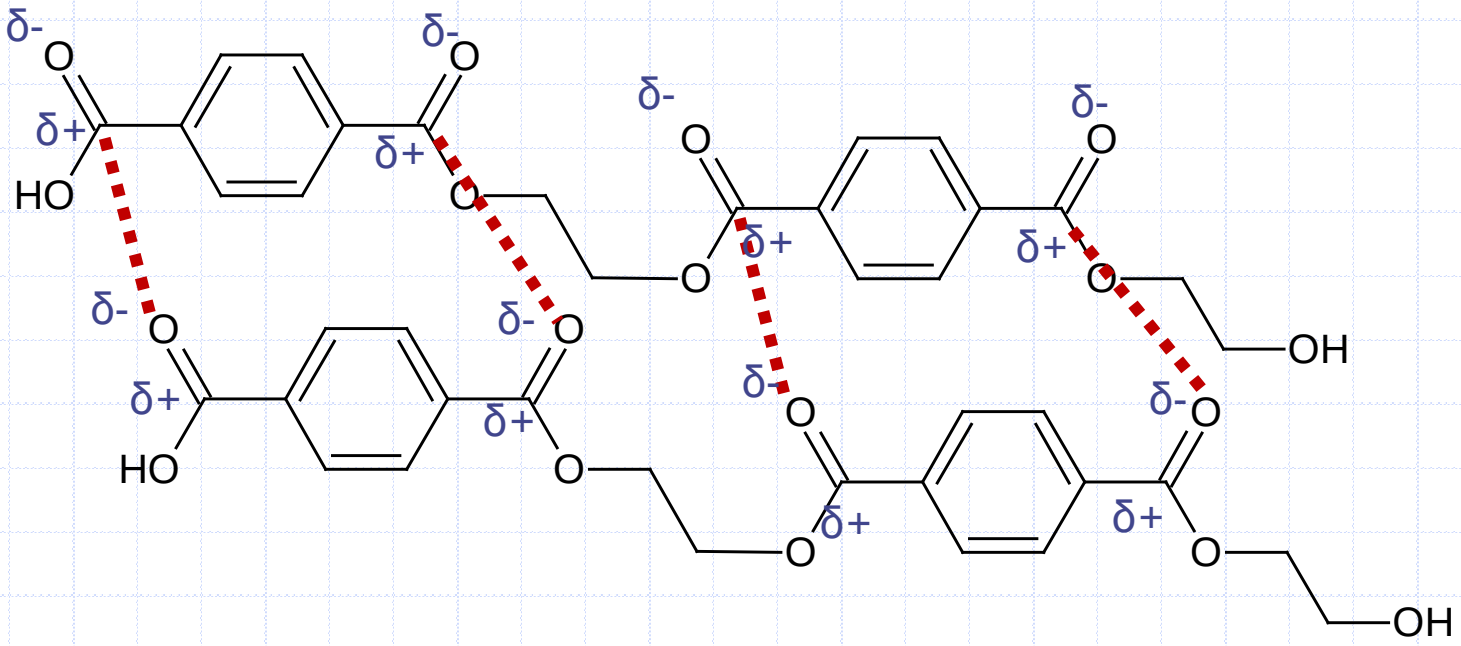
Intermolecular Attraction of Polymers

- The dipole/dipole interactions between the polar chains can interact with one another for use in shirts, plastics, etc depending on the individual properties.
- Below is terylene (Dacron) which is used to make clothing in cotton/polyester blends



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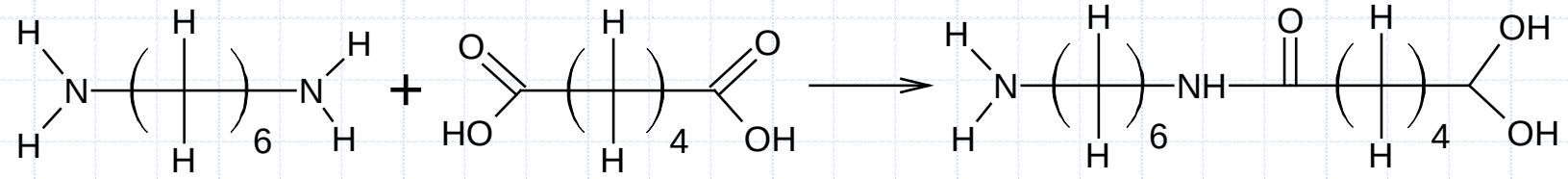
Amines and Carboxylic Acid Reaction: Nylon

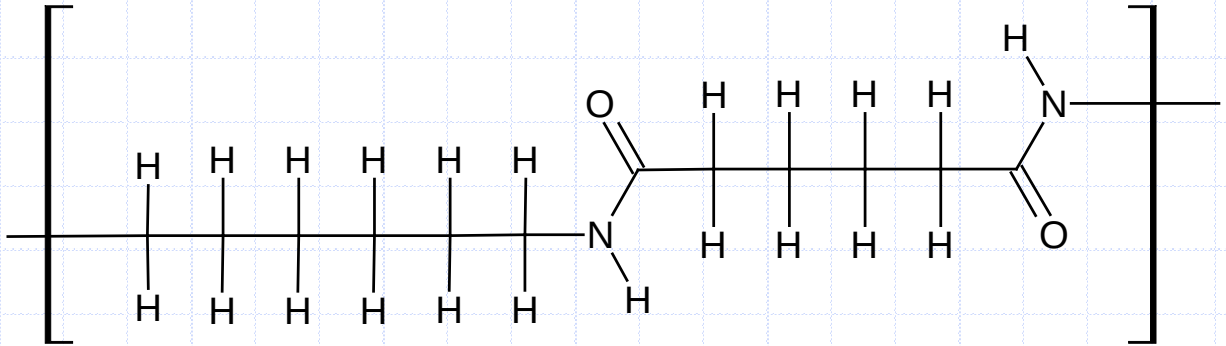
20.4.4 Deduce the structures of the polymers formed in the reactions of amines with carboxylic acids. (3)

- Nylon is found to be very useful in many compounds, it's production is from the polymerization of amines and carboxylic acids:



1-6-diaminohexane Hexane-1,6-dioic acid nylon-6,6

- The two monomers each contain six-carbon chains, so it's known as nylon-6,6
- The repeating unit is as follows:



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Nylon in Industry

- Reactions to form Nylon are carried out under vacuum conditions to remove the released H_2O
- Nylon is known as a **polyamide** and contains the same link as in polypeptides (proteins), known as a **peptide bond**
- Nylon is produced in the solid form and can be melted and forced through jets which produce long filaments called **nylon fibers**
- This resultant product can be woven into a yarn for the production of rope, fabric, parachutes, etc
- The chains interact through hydrogen bonding between the N-H groups and the C=O groups.

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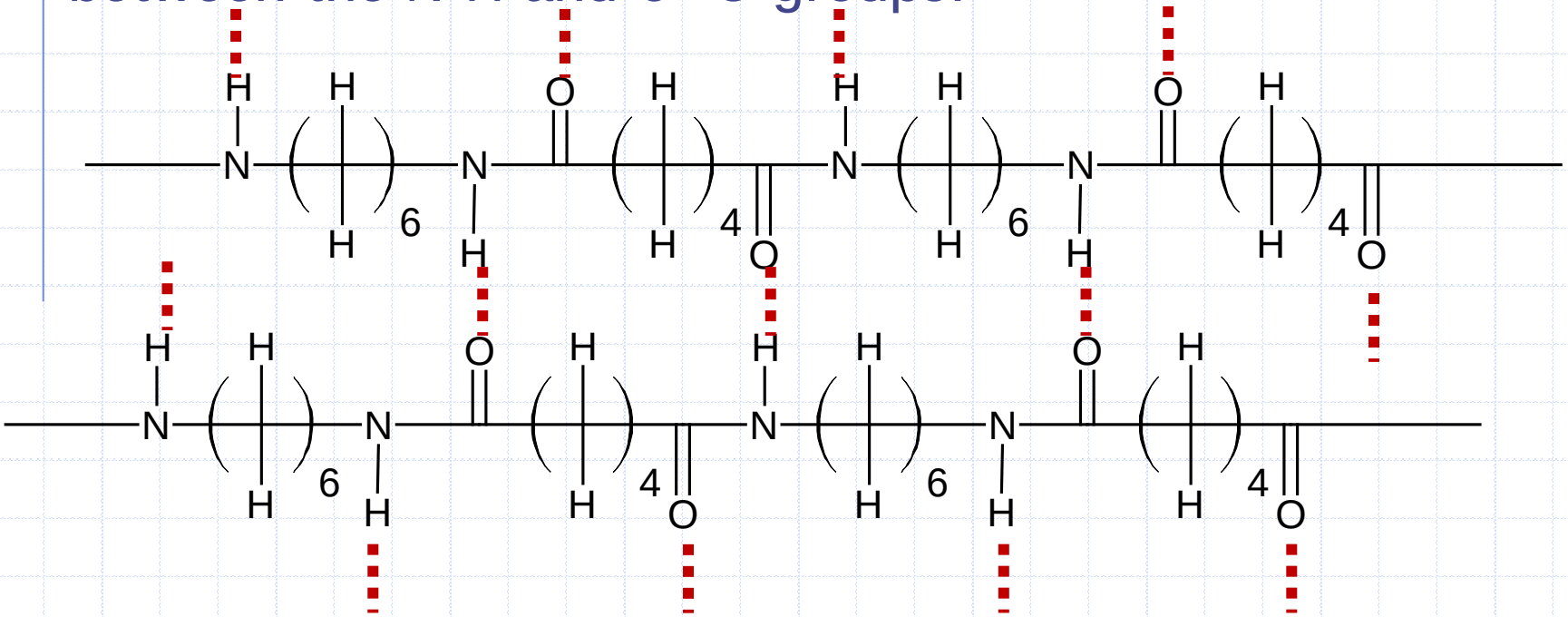
Hydrogen Bonding in Nylon

- As discussed, the chains are held by hydrogen bonds between the N-H and C=O groups:



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Further uses of Polyamides

- Due to the single covalent bonds in Nylon, the chains are free to rotate and make the polymer quite flexible.
- In **Kevlar**, the replacement of the benzene ring for the hydrocarbon chain disrupt flexibility making it more rigid and five times the strength of steel (weight for weight)
  - A benzene ring can be inserted in place of the hydrocarbon chain to produce an **aramid polymer** such as Kevlar.
- **Proteins** are natural polyamides consisting of long chains of amino acid residues

Economic Importance

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20.4.5 Outline the economic importance of condensation reactions. (2)

- The world production of Nylon is estimated to exceed 5 million tonnes.
  - Clothes, carpets, rope, etc
  - High strength, resists abrasion, easy to die
  - Used in engineering (gears, etc)
- Kevlar is used to reinforce many materials